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**COST BENEFIT ANALYSIS IN MILITARY MANPOWER  
AND TRAINING RESEARCH AND DEVELOPMENT:  
CURRENT PRACTICES**

**James S. McMichael  
Director, Training Laboratory  
Navy Personnel Research & Development Center  
San Diego, CA 92152-6800**

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**Paper presented at:  
Symposium on the Military Value and Cost-effectiveness of Training  
NATO  
Brussels, Belgium**

**7 January 1985**

**85 8 26 224**

## REPORT DOCUMENTATION PAGE

AD-A152 525

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release. Distribution unlimited.		
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S)			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION Navy Personnel Research and Development Center		6b. OFFICE SYMBOL (if applicable) Code 05		7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) San Diego, CA 92152-6800				7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING / SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (if applicable)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code)				10. SOURCE OF FUNDING NUMBERS	
PROGRAM ELEMENT NO.		PROJECT NO.		TASK NO.	
				WORK UNIT ACCESSION NO.	
11. TITLE (Include Security Classification) Cost Benefit Analysis in Military Manpower and Training Research and Development: Current Practices					
12. PERSONAL AUTHOR(S)					
13a. TYPE OF REPORT FINAL		13b. TIME COVERED FROM 9-82 TO 6-83		14. DATE OF REPORT (Year, Month, Day) January 1985	
				15. PAGE COUNT 26	
16. SUPPLEMENTARY NOTATION Paper was initially developed under a mid-career fellowship at the Woodrow Wilson School of Public & International Affairs, Princeton, University, and later presented at the Symposium on the Military Value and Cost-effectiveness of Training, NATO, Brussels, Belgium, 7 January 1985.					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP			
05	09		economic analysis; cost-benefit analysis; manpower; personnel; training		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The goal of this study was to determine what current theory and practice in cost-benefit analysis (CBA) may have to offer toward improving the application of CBA tools in the Department of Defense, specifically their application to decision making in the human resources areas of manpower, personnel and training (MPT). A survey was made of the cost-benefit analysis literature to develop a taxonomy of generally accepted and widely used techniques and analytic precepts. The survey identified fourteen economic precepts and principles applicable to CBA; they were associated with two major foundations of CBA, financial analysis and welfare economics. Associated with financial analysis were the following seven elements: formulating the objective; specifying alternatives; determining the accounting stance; establishing decision criteria; discounting; conducting sensitivity analyses; formulating production functions. Associated with welfare economics were the following six elements: shadow pricing; establishing commensurability of costs and benefits; evaluating risk bearing; accounting for externalities; evaluating intangibles; measuring					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED / UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code) (619) 225-6466		22c. OFFICE SYMBOL

UNCLASSIFIED

19. ABSTRACT (continued)

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A sample of analyses reported in the technical literature of the Department of Defense MPT research and development community was examined to determine which of these techniques and precepts were and were not generally used and followed.

There was an uneven pattern of applications. Current practice was found to apply the financial-analysis elements more often than those based on welfare economics. An exception to this generality was the development of production functions, a financial-analysis element that was not applied in the sample of reports.

Improvements in current practice in the Department of Defense could be made by uniformly applying the financial-analysis elements properly, by developing applications of production functions, and by drawing on elements based on welfare economics such as assessing distributional effects, including intangibles, using shadow prices, and assessing externalities.

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DTIC TAB	<input type="checkbox"/>
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A-1	



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## ABSTRACT

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# **COST BENEFIT ANALYSIS IN MILITARY MANPOWER AND TRAINING RESEARCH AND DEVELOPMENT: CURRENT PRACTICES**

## **1. INTRODUCTION**

Cost-benefit analysis is the name given to a set of techniques used to aid the process of planning the expenditure of public funds. It is used to evaluate and compare specific investment projects that a governmental entity is considering, and it is used to evaluate the likely consequences of various policy options. It functions as a tool to identify projects having the potential to increase economic efficiency.

Cost-benefit analysis is an applied specialization within the science of economics, and most of the research, application and scholarship is done by economists. Examples of applications include selecting a site for a new airport, valuing proposed recreational facilities, developing new industries in less developed countries, and allocating the consumption of exhaustible resources among present and future generations. Within this broad context and over the past two decades or so, economists and mathematicians have confronted major theoretical issues and have developed a variety of analytic tools for dealing with real world problems.

Department of Defense Instruction 7041.3 (DoDINST 7041.3), "Economic Analysis and Program Evaluation for Resource Management," 18 October 1972, mandates the use of cost-benefit analysis in the military services and prescribes many of the specific procedures to be followed. Each service has implemented Department of Defense policy through its own instructions and regulations, and many quasi-official handbooks, guides, and reports have been written to assist users.\* Military analytic methods have been closely associated with the disciplines of operations research, engineering, and systems analysis, perhaps in part because cost-benefit analysis in the military was given impetus by the Planning, Programming, and Budgeting (PPB) system.

### **1.1. Objective**

The goal of this study was to determine what current theory and practice in cost-benefit analysis may have to offer toward improving the application of these tools in the Department of Defense, specifically their application to decision making in the human resources areas of manpower, personnel and training. There were three parts to this research: (1) A survey was made of the cost-benefit analysis literature to develop a taxonomy of generally-accepted and widely used techniques and analytic precepts; (2) A sample of analyses reported in the technical literature of the Department of Defense manpower, personnel and training research and development community was examined to determine which of these techniques and precepts were and were not generally used and followed; (3) From the results of steps (1) and (2), conclusions were drawn about the potential for improving the practice of cost-benefit analysis within that community. While the approach involved comparing published reports to a theoretically-derived ideal, the purpose was not to evaluate the work represented in these reports. The reports served to isolate those methods that economists have used that might have the potential to improve future cost-benefit analyses.

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\* One such handbook, which is comprehensive, consistent with DoDINST 7041.3, and easy to follow, is the *Economic Analysis Handbook*, 2nd ed. [28]

## 1.2. Theoretical Background

Why should there be any question of the applicability to defense programs of the techniques of cost-benefit analysis that economists use? The principal objective is the same, maximizing economic efficiency, i.e., getting society the most benefit possible out of the productive resources that government consumes.

Part of the answer lies in differences between national defense and many other governmentally-provided services. National defense is provided to every member of the society equally and is a service that is not exchanged in any marketplace. In a very real sense its production and consumption by the society are a single act. Consequently, placing a value on the product of the military is a thorny problem. The problem is especially difficult when one is measuring benefits associated with the intermediate products that come from programs in manpower, personnel, and training. By contrast with defense, other government-produced goods and services, such as parks or public universities, principally benefit those who use them. Even though there may be no charges levied on the users, economists do have ways of estimating the value of these benefits that are independent of the costs of producing them.

A second part of the answer lies in the differing planning and decision-making contexts within which cost-benefit analyses are conducted. Defense objectives originate with the Congress and the Executive. Specific programs and projects are valued in terms of how well they support these objectives, and resources are allocated according to decisions made in this context. In many other governmental applications the objective of a cost-benefit analysis is to synthesize a public policy out of the individual value judgments made by those who will potentially be affected by a proposed project. A new airport, for example, will benefit those who use its services while costing the taxpayers of a particular region and those who suffer the noise, congestion, and pollution it brings. The analysis will try to put all these economic costs and benefits together into one or more measures of the economic-welfare consequences associated with the decision. Because defense settings differ from other government contexts, one should expect that the tools of cost-benefit analysis will vary in how often they are used by Department of Defense analysts and in how much they will have to be tailored to meet Department of Defense needs.

The tools of cost-benefit analysis have theoretical roots in two specialties within economics, financial analysis and welfare economics.

### 1.2.1. *Financial Analysis*

Also called profitability analysis, financial analysis is used as a decision-making aid in business and industry much as cost-benefit analysis is used in government. Sound financial management practices are essential to good government, and many of the concepts and tools of cost-benefit analysis in government are the same ones used privately.

Some of the concepts to be discussed in the next section of this report have their roots in financial analysis: investment, discounting, present value, future value, risk, and production functions.

### 1.2.2. *Welfare Economics*

If profitability analysis tends to focus on monetary profits, welfare economics deliberately takes a broad societal view of both costs and benefits. It is the overall well-being (hence "welfare") of society that is of interest. Economic efficiency is generally defined in terms of Pareto optimality, which is that condition in which it is no longer possible to make any one member of society better off without making another worse off. In practice, the Pareto optimality principle is combined with the Kaldor-Hicks principle of compensation to give a social cost-benefit

criterion. The latter principle states that the outcome of a proposed project or policy is superior providing the potential gainers could *compensate* the losers for their losses and still have a net gain or, conversely, that the potential losers could pay the gainers an amount *equivalent* to their potential gains and remain better off than were the project not undertaken. The Kaldor-Hicks principle does not require that these transfers actually take place, just that they could be made. Taxes, unemployment compensation and other government transfer programs are assumed to effect socially-desired redistribution of wealth.

Willingness-to-pay is a fundamental concept of welfare economics that underlies the measurement of a proposed project's costs and especially its benefits. The market price can be a direct measure of willingness-to-pay, provided the products are freely traded. Many public goods are not traded, e.g., access to public parks, or their price is kept artificially low, e.g., subsidized public universities, so benefits are not properly measured by what people actually pay. Similarly, the resources consumed by a public project may not be worth what the government pays for them, using "worth" to mean the value of what society foregoes in using it.

Some of the concepts used in the next section of this report have their roots in welfare economics: compensating variation, equivalent variation, shadow prices, externalities, intangibles, distributional effects.

### 1.3. Terminology

*Cost-benefit analysis* can be defined as "an estimation and evaluation of net benefits associated with alternatives for achieving defined public goals." (Sassone and Schaffer [8] p. 3.) It is a general term for the tools and techniques that are used to assist government agencies to decide whether the social benefits of projects and policies outweigh their costs. The implication is that costs and benefits are measurable in the same units, usually dollars, although in practice the term is used when commensurability is not entirely achieved.

*Economic analysis* is a term favored in Department of Defense publications and having the same meaning as cost-benefit analysis but without the connotation of commensurability of costs and benefits. The Department of Defense *Economic Analysis Handbook* [28, p. 2] says, "An economic analysis postulates alternative means of satisfying an objective and investigates the costs and benefits of each of these alternatives."

*Cost-effectiveness analysis* "is a [cost-benefit analysis] with benefits not defined in the same terms as costs." (Sassone and Schaffer [8] p. 36) This term specifically implies that commensurability is lacking; costs are expressed in dollars and benefits are measured in their own units, usually along as many dimensions as possible to reflect the full spectrum of effects. Cost-effectiveness analyses are common in the Department of Defense. Frequently the effectiveness of the alternatives is known or assumed to be equal, and the analysis seeks to find the one having the least cost.

## 2. APPROACH

Determining which cost-benefit analysis precepts and practices might have the potential for improving economic analysis in DOD manpower, personnel, and training programs involved comparing a sample of such analyses to a set of economic precepts and practices. The sample was taken from reports published by the laboratories in each service having responsibility for manpower, personnel, and training research and development. The set of precepts and practices was derived from a taxonomy of economic principles that was developed by surveying literature in economics. The emphasis of this survey was on secondary sources on cost-benefit analysis. Table 1 displays the set and gives at least one reference for each element. The rest of this section describes the approach used to develop the taxonomy and to select the sample.



Table 1. Economic Precepts and Practices Applicable to Economic Analyses

ELEMENT	DEFINITION	REFERENCE(s)
OBJECTIVE	A precise statement of goals and purposes.	Sugden & Williams [27] p. 4 ff Anderson & Settle [2] pp. 116-118 Sassone & Schaffer [8] pp. 158-159
ALTERNATIVES	Possible courses of action, including the <i>status quo</i> , to be analyzed and subjected to the decision.	Sassone & Schaffer [8] pp. 158-159
ACCOUNTING STANCE	Scope or range of organizations or individuals to whom costs and benefits are taken to accrue.	Anderson & Settle [2] pp. 19-20 Sugden & Williams [27] pp. 95-98
DECISION CRITERIA	An objective-based statement of the basis for decision making.	Sugden & Williams [27] p. 235-241 Anderson & Settle [2] pp. 13-29
DISCOUNTING	Reducing the value of future cash flows according to prescribed formulas or factors.	Sassone & Schaffer [8] p. 14
COMMENSURABILITY	Measuring all costs and benefits in the same units.	Dasgupta & Pearce [25] p. 112 ff Sassone & Schaffer [8] pp. 34-37
PRODUCTION FUNCTION	Mathematical specification of the input-output relation for the product of a project.	Intriligator [7] p. 362 ff
RISK BEARING	A potential source of benefits from reducing variance rather than increasing the average benefit.	Pearce & Nash [26] p. 69 ff
SHADOW PRICE	The marginal value of a unit of input measured in terms of units of output.	Squire & van der Tak [9] p. 26 Mishan [1] pp. 81-90
EXTERNALITIES	Uncompensated costs and unpriced benefits accruing outside the scope of the project.	Dasgupta & Pearce [25] p. 118 ff Anderson & Settle [2] p. 63 ff
INTANGIBLES	Effects that are not (readily) measurable.	Anderson & Settle [2] p. 23 ff Sassone & Schaffer [8] p. 31 ff
DISTRIBUTIONAL EFFECTS	Benefits differentially received or costs differentially borne across members of society.	Squire & van der Tak [9] pp. 49-77, 101-117 Mishan [1] pp. 392-396, 403-406 Sugden & Williams [27] pp. 201-207 Anderson & Settle [2] pp. 106-110 Sassone & Schaffer [8] pp. 131-138
SENSITIVITY ANALYSIS	Systematically varying assumptions and parameter values to identify important variables.	Sassone & Schaffer [8] pp. 134-154
RETROSPECTIVE EVALUATION	Cost-benefit analyses done after a project to verify prior estimates.	Merewitz & Scanick [10] p. 217 ff

## 2.1. Taxonomy of Economic Principles for Cost-benefit Analysis

### 2.1.1. Decision Framework

The first step in cost-benefit analysis is to determine the framework, or context, in which a decision is to be made. What are the objectives? What assumptions are being made? What are the alternative projects or policies (including the *status quo*)? What is the relevant time in which the project may be done and its benefits realized? What is the proper accounting stance to adopt (society as a whole, a region, a governmental agency, etc.)? What criteria are to be used in reaching the decision?

#### **2.1.1.1. Objectives.**

Rational choice depends on having a defined goal. It may be the general one of increasing the economic well being of a society or it may be very specific. Stating the objective(s) guides the later steps in an analysis and helps ensure that the data gathered by the analyst bear on the issues that are important to the decision or policy maker. This straightforward observation implied the first precept:

**OBJECTIVE:** The analysis should begin with a statement of purposes and goals that is precise enough to measure the project's success.

#### **2.1.1.2. Alternatives.**

The proposed project may not be the only way to achieve the objectives, and there is always the possibility of continuing present policies. It is helpful to have as many alternatives analyzed as feasibly can be considered. At a minimum, one alternative to the proposed project, probably the null choice, should be described and should be analyzed to the same degree of specificity as the proposed one.

**ALTERNATIVES:** The analysis should include at least one alternate to the proposed policy or program, usually the continuation of the status quo, and preferably as many alternates as could reasonably be considered.

#### **2.1.1.3. Timing.**

Two different questions may arise. One concerns the economic life of a project and hence the planning horizon for the analysis. The appropriate horizon varies with the economic assets, and there are no significant theoretical insights to be drawn. The second type of question concerns finding the optimal time to begin a project. This issue can be addressed under the rubric of "alternatives" or as part of "sensitivity analysis," which is discussed later in this section.

#### **2.1.1.4. Accounting Stance.**

From what or whose perspective are costs and benefits to be reckoned? Sometimes the answer is so obvious that it need not be stated. A project intended to benefit society as a whole should have an accounting stance that includes costs and benefits to everyone, and the classical welfare-economics approach takes this stance [1]. The analyst should use a perspective at least as broad as the organizational level at which the decision is to be made [2]. It is most important that the analysis include all significant benefits and costs and that it be consistent in using whatever accounting stance is chosen.

**ACCOUNTING STANCE:** The set of individuals or organizational entities whose costs and benefits are included for analysis should be defined (or clearly implied) and used consistently in the analysis.

#### **2.1.1.5. Decision Criteria.**

Once costs and benefits have been fully accounted and analyzed, some mechanism must exist for making a decision. The decision criterion can take many forms and may be made up of several independent criteria, depending on the objectives, whether the analysis is cost-benefit or cost-effectiveness, whether benefits are commensurable, the importance of intangible costs and benefits, how distributional effects are reckoned, and similar considerations.

**DECISION CRITERIA:** One criterion, or a set of related criteria, should be chosen to reflect the objectives. It (they) should be made explicit so that the analysis can focus on the relevant data.

#### 2.1.1.6. *Discounting.*

Closely related to the choice of decision criteria is the question of how to compare costs and benefits that accrue at different times. This question is especially important when the profiles of costs and benefits over time are different for each alternative, which is characteristically the case.

A dollar now is not the same as a dollar a year from now; it is worth more. This is so because (1) members of our society in general prefer present consumption to future consumption, (2) to borrow money for current expenses the government must pay interest, and (3) money not spent for governmental purposes is available for private investment, which will yield a return. Some technique is needed to make costs and benefits accruing at different times commensurable, and the technique is called discounting. The most sound procedure is to express all cash flows in constant-value terms by multiplying each year's outlay by a present-value factor from the expression,  $(1+i)^{\text{base year-outlay year}}$  where  $i$  is the annual discount rate. Normally the base year is the first year of the project, and net *present* value (NPV) is used in the decision criterion, but for some investment projects it may be more sensible to use the last year of benefits as the base and to use net *terminal* value (NTV) instead. Under conventional assumptions about discount rates, NPV and NTV will be different values but will lead to identical decisions. Tables of present value factors are available; some use the expression above directly, some assume continuous compounding, and some assume continuous outlays.

It is a serious error not to discount (or compound) cash flows to a common point in time and instead to compare total raw costs or a similar parameter such as average annual cost. Not to discount is contrary to DoDINST 7041.3 and introduces a bias in favor of alternatives that involve research and development, equipment purchases, and other forms of initial investment. If the analyst also is seen as having a stake in such an alternative, not discounting may threaten the credibility of the entire analysis.

**DISCOUNTING:** Project cash flows occurring over time must be discounted to a common point before being aggregated into a single value.

#### 2.1.2. *Cost Measurement*

##### 2.1.2.1. *Cost Estimating.*

Accounting for all the raw costs associated with a project or policy is a major task and one that is not always done well. In general, one can use the industrial engineering model, which bases estimates on work-breakdown structures, or one can use cost-estimating relationships (CERs), or one may combine the two approaches. The techniques tend to be specific to the substance of the program being analyzed. The *Economic Analysis Handbook* [28], Chapter 3, provides general guidance for defense projects. For specific topics there are specific sources that are known to the scientists, engineers, and managers who work in those areas. Useful sources for training projects include Swope and Green [3]; Allbee and Semple [4]; Matlick, Rosen, and Berger [5]; and Knapp and Orlansky [6]. Knapp and Orlansky present a comprehensive set of elements to encompass all costs for formal training programs, courses, and training devices. Because the principles come more from engineering than economics, Table 1 did not receive an entry for cost estimating.

### 2.1.3. Benefit Measurement

#### 2.1.3.1. Willingness to Pay.

Benefits in social cost-benefit analysis are normally valued according to how much members of society in the aggregate are willing to pay to receive them. If all of a government project's outputs are freely traded, then market prices can measure willingness to pay. In such cases one can apply profitability-analysis techniques directly, as is done in the private sector. Often the products of government projects are not free-market goods, so special techniques are needed.

There are three common ways of estimating willingness to pay from economic data. One is directly to estimate a consumers' demand function that relates the amount of the good demanded and its price. Then, the area under this curve and above the market price (consumer surplus) can be taken as a measure of benefit received. Second, one could ask: Instead of doing the project, how much would one have to pay the beneficiaries to make them equally well off (equivalent variation)? Third, one could ask the similar question: Given that the project is carried out, how much could one take away from the beneficiaries and leave them equally well off as before (compensating variation)? Any of these three measures can be used to estimate benefits; it is known theoretically that the value of the first, consumer surplus, must lie between the other two.

Addressing the problem of valuing the benefits of military training, Sassone\* has noted a formal similarity between consumer demand curves and production functions. Holding effectiveness constant and measuring savings is similar to measuring willingness-to-pay by equivalent variation. The point developed by Sassone is that models analogous to willingness-to-pay could provide estimates of training benefits in the same units (dollars) as the costs.

**COMMENSURABILITY:** Costs and benefits should be measured in the same units.

#### 2.1.3.2. Production Function.

Sassone's method for using "consumer surplus" to measure benefits requires that one first develop a production function econometrically. Basically following Intriligator [7], Sassone suggests several possible forms for the production function and notes the parametric estimation requirements of each. Once the function and its parameter values are specified, productivity of training components, economic values, and present values can be calculated for use in cost-benefit analysis.\*\*

**PRODUCTION FUNCTION:** A mathematical statement of the relationship between inputs and outputs should be developed and used to relate costs and benefits.

#### 2.1.3.3. Risk Management.

One benefit of a project may be that it reduces the risk and uncertainty that the beneficiaries must bear in their own production or consumption of goods and services; this effect may be independent of the project's average benefit to them. Reducing the risk that

\* Sassone, P. G. The economic evaluation of military training. (undated) Unpublished manuscript. The Georgia Institute of Technology.

\*\* Sassone's approach confronts the problem of incommensurability of costs and benefits. The result, however, is not strictly one of consumer willingness-to-pay, because values ultimately derive from how much is paid for factor inputs rather than what is paid for outputs. The approach therefore is not a completely satisfactory way to monetize benefits for a true cost-benefit analysis.

must be borne is called the insurance value of a project and should be included as a benefit. For example, a project that reduced year-to-year fluctuations in crop yields would have economic benefits for farmers even if the average yield did not change. Likewise, a program to smooth out the seasonal and cyclic flows of volunteers for military service has the value of reducing uncertainty about personnel availability. By the same token, projects that increase risk and uncertainty may have hidden costs.

**RISK BEARING:** The value of changes in the variance of benefits should be included.

#### **2.1.3.4. Shadow Pricing.**

Raw costs, it was previously noted, are not always the best measures of the value to society of a resource consumed by a project. A shadow price is "a value associated with a unit of some good which indicates how much some specified index of performance can be increased (or decreased) by the use (or loss) of the marginal unit of that quantity." [8] From a societal point of view the shadow price of a commodity or factor of production is the value of its contribution to a basic social objective [9] such as Gross National Product. In other words, shadow prices are either corrected market prices or they are imputed prices for nonmarket goods. Shadow prices are in dollar units when the objective function is in dollars. When the objective is in other terms, say military readiness, then shadow prices would be in the units were used to measure that objective.

**SHADOW PRICING:** When a market price for a good is (1) unavailable, (2) an invalid measure of its value to society, or (3) not expressed in the units of the objective function, a shadow price should be estimated and used.

#### **2.1.3.5. Externalities.**

An external effect occurs when one person's consumption or production affects another's without there being a market for the effect. In other words, externalities are, "benefits involuntarily received by others for which they pay nothing (and) costs imposed on others without compensation" [8]. Their significance is that they distort market prices, because with externalities social costs are not equal to private costs. The pollution accompanying an airport is a common example for a negative externality. Analogous effects can distort military analyses as for example if reduced training in one school forces an increase in training in a follow-on school. Taking a broad accounting stance and using shadow prices are two ways to incorporate external effects in a social cost-benefit analysis.

**EXTERNALITIES:** When costs are borne or benefits received outside the scope of the project, accounting adjustments (e.g., shadow pricing) should be incorporated into the analysis.

#### **2.1.3.6. Intangibles.**

Some effects are at best difficult to measure, and some are impossible in principle to measure. Safety, life, limb, job satisfaction, and national security are often-cited examples because they are intangible in the sense that they are "not susceptible to being measured in dollar terms" [2]. The mistake is to exclude them from the analysis. If the project's benefits are substantially intangible, one can at least list and possibly, quantify them. The decision maker can then weigh these benefits against the project's net cost.

**INTANGIBLES:** Outcomes that are not susceptible to being measured at all or at least not in dollar terms should not be excluded from a cost-benefit analysis.

#### 2.1.3.7. *Distributional Effects.*

Cost-benefit analysis is principally addressed to the question of economic efficiency, i.e., do benefits outweigh costs? Yet, the benefits and costs of a project do not necessarily accrue equally to everyone, and various alternative projects are likely to have differing distributional consequences. There are three ways to treat the distributional issue in a cost-benefit analysis: (1) Ignore them and assume taxation and government transfer programs will rectify inequities. (2) Establish explicit distributional weightings so that, say, benefits to the rich count less than equal dollar benefits to the poor. (3) Assess and report distributional effects in the analysis separately from valuing costs and benefits. This latter approach identifies gainers and losers and is sometimes called social-impact analysis. "Social impacts are effects on the distribution of income as well as on the psychological, social and physical well-being of individuals affected by a project." [8] Intangible and incommensurable benefits can conveniently be included in an impact analysis.

**DISTRIBUTIONAL EFFECTS (Impact Analysis):** The analysis should at least identify the gainers and losers and how they are affected. It may be possible to use distributional weights in the analysis.

#### 2.1.3.8. *Sensitivity Analysis.*

There is bound to be some uncertainty in the assumptions and parameters used in any cost-benefit analysis. Would the decision be different under different assumptions? A different discount rate? A later start-up time for the project? Sensitivity analysis provides answers by varying parameters to see which variables are important. The sensitivity analysis may even shed more light on the decision-making process than the estimate of economic benefit.

Two useful variants of sensitivity analysis are contingency analysis and *a fortiori* analysis. In the former, one redoes the analysis under assumptions of particular interest, e.g., mobilization conditions. In the latter, one deliberately selects parameter values and assumptions that would work against the proposed alternative. The admittedly questionable rationale of such a "worst-case" analysis is that, if the proposal can withstand such a test, it must be a strong one.

**SENSITIVITY ANALYSIS:** To deal with errors and uncertainties in parameters and assumptions and to identify important variables, a systematic sensitivity analysis should be undertaken.

#### 2.1.3.9. *Retrospective Evaluation.*

Much can be learned by reevaluating a project once it is well underway or after it has been completed. A survey by Merewitz and Sosnick [10] found that cost estimates were low in 80 percent of the analyses. By contrast, successful research and development projects often have benefits that go far beyond those originally envisioned, and this should be documented for policy makers. In this category too are the several excellent cost-effectiveness studies on training technology by Orlansky and String [11] [12] [13].

**RETROSPECTIVE EVALUATION:** Conducting or reworking a cost-benefit analysis during or after a project will provide valuable insights for policy and for future analyses.

## **2.2. Manpower, Personnel, and Training Analyses**

### **2.2.1. Sampling Method**

The economic analyses included in this research were selected from reports published since 1976 by the Department of Defense laboratories that are principally responsible for manpower, personnel, and training research and development:

Army Research Institute for the Social and Behavioral Sciences (ARI)  
Air Force Human Resources Laboratory (AFHRL)  
Naval Training Equipment Center (NTEC)  
Navy Personnel Research and Development Center (NPRDC)  
Training Analysis and Evaluation Group (TAEG, now part of NTEC)

The objective was to identify comprehensive, high-quality economic analyses, not to select a representative or random set. This approach was consistent with the purpose of the research being not to evaluate the analytic work but rather to determine which principles of cost-benefit analysis as practiced by economists have the potential to improve practice within the DOD manpower, personnel and training community. Only original reports of project-level economic analyses were considered; excluded were meta-analyses (e.g., the Orlansky and String reports cited earlier), secondary sources, cost-estimating reports (e.g., the Navy's billet cost model), and reports describing economic-analysis models or techniques (e.g., Swope and Green [3]).

### **2.2.2. The Sample of Projects**

Economic-analysis reports were selected for each of the projects described below.

#### **2.2.2.1. Computer-based Instruction for Trident Training (Trident).**

Kribs [14] compared three candidate computer systems for training personnel to be assigned to Trident submarines. The economic analysis identified the most cost-effective system, which the Navy purchased.

#### **2.2.2.2. Performance-contingent Reward System (PCRS).**

Developed for use by Navy shipyards the PCRS is an incentive program to improve the productivity of civilian shipyard employees. The program was successfully implemented in the key-entry sections of the data-processing departments of two shipyards. "Key entry" is the process of manually entering information from various source documents into a computer. Bonuses were awarded to workers whose productivity exceeded objective performance standards according to a system devised by the researchers. The economic analysis was conducted after initial trials at one shipyard [15]. The research project was continued at this and other facilities.

#### **2.2.2.3. Advanced Naval Engineering Maintenance Training Program (MAINT).**

Modern steam propulsion plants are controlled automatically by systems that sense the outputs (e.g. smokestack exhaust) and the operations of the plant and control it through a network of pneumatic and electromechanical controls. The Naval Training Equipment Center developed a simulator to train technicians to maintain one such automatic boiler control

system, and the Allen Corporation of America [16] evaluated a training program that used this simulator in comparison to the traditional training program covering the same general curriculum.

#### **2.2.2.4. Marine Corps Computer-based Education (MCCBE).**

VanMatre, Pennypacker, and Bortner [17] developed a plan for using computers in Marine Corps electronics training. They then conducted an economic analysis comparing implementation of the plan to continuing the status quo, a lecture-based training program.

#### **2.2.2.5. Officer Career Information and Planning System (OCIPS).**

Myers, Cairo, Turner, and Ginzberg [18] devised a plan to develop an Army career information system from a prototype into operation, and they reported the costs and benefits of doing so.

#### **2.2.2.6. 6883 Maintenance Training Simulator (6883).**

The Air Force Human Resources Laboratory developed an experimental simulator to train technicians to maintain electronic test equipment. Cicchinelli, Harmon, Keller, and Kottenstette [19] of the Denver Research Institute compared its effectiveness and cost with using the actual test equipment. They found that both were equally capable of training the students and that the simulator was the less costly alternative.

#### **2.2.2.7. Performance Related Enabling Skills Training (PREST).**

The services have several programs to provide remedial training in basic skills, especially language and computational skills, to recruits who need to reach adequate levels of competency for further training. PREST is a computer-based program that the Navy has used. Wisher and O'Hara [20] compared the effectiveness and costs of PREST with the standard classroom approach to remedial training. They found equal effectiveness and a higher cost for PREST, but they projected that future decreases in computer costs would lead to its becoming cost-effective in the future.

#### **2.2.2.8. MA-3 Electromechanical Test Stand Simulator (MA-3).**

The Naval Training Equipment Center developed an experimental device to train technicians to maintain a particular piece of electromechanical equipment, the MA-3 test stand. Garlich [21] evaluated the device's training effectiveness and reported on the costs of using it.

#### **2.2.2.9. Electronic Equipment Maintenance Training System (EEMT).**

This project developed a general-purpose computer-based simulator for training technicians to maintain electronic equipment such as radars and communication equipment. The EEMT consisted of a microcomputer with a video display for alphanumeric information, a color videodisc player, and monitor to display images of electronic equipment and test equipment, and touch panels over the displays to allow students to interact with the computer-controlled simulation. Twenty prototype devices were constructed, programmed, and tested. The economic analysis was done while the prototypes were being constructed. It evaluated the choice of buying production models of the EEMT against using actual electronic equipment [22]. The Navy has since purchased more than 100 of these EEMT units.



#### **2.2.2.10. Enlisted Personnel Individualized Career System (EPICS).**

It is common practice in the Navy to train personnel in shore-based schools until they become skilled technicians and then send them to fleet units to use and upgrade their skills on the job. EPICS is a project that seeks to reduce personnel costs by reducing such front-loaded training in favor of interspersing training on-the-job and in school with fleet assignments earlier in the enlisted person's career. Megrditchian [23] analyzed costs of an experimental application of the EPICS concept in comparison to the conventional approach and found potential savings.

#### **2.2.2.11. Recruit Preparation and Orientation Training (REPORT).**

Attrition from the Navy had become a problem among certain groups of enlistees. This work targeted seaman apprentices who enlisted without a guarantee of schoolhouse technical training and who would therefore become part of the general detail aboard the ships to which they were assigned. Fernandes, Bearden, and Felter [24] developed and tested a three-day training program for these recruits. It produced a modest reduction in training attrition that was sustained in the fleet. The analysis showed a substantial net benefit in productive service time in the Navy for those in this experimental training program.

### **2.3. Analysis of the Economic Analysis Reports**

Each report was examined to determine whether the economic analysis included the elements of cost-benefit analysis in Table 1. If not, there was no entry in Figure 1 for that particular element. Use or nonuse of each element was the major datum in this research.

Given that a technique was used, a rough determination was made of how closely the application came to a theoretical ideal presented in the references cited in Table 1 for that technique. A five-point scale was used to produce the entries in Figure 1:

- ++ An exemplary application.
- + Fully consistent with theoretical guidelines.
- Not applicable, or used differently from guidelines.
- Flawed, by theoretical standards.
- Technique improperly applied.

### 3. RESULTS

Figure 1 displays the pattern of use of each of the fourteen selected elements of cost-benefit analysis in the sample of manpower, personnel and training economic analyses. The results are then described element-by-element.

	T r i d e n t	P C R S	M A I N T	M C C B E	O C I P S	6 8 8 3	P R E S T	M A - 3	E E M T	E P I C S	R E P O R T
Objective	+	+	+	+	+	-	+	-	+	+	+
Alternatives	++	+	+	+	+	+	+	+	+	++	+
Accounting Stance	○	○	○	○	○	○	○	○	○	○	○
Decision Criteria	+	+	+	+	-	+	+	○	+	+	+
Discounting	-	++	-	+		-	-		-	+	+
Commensurability											+
Production Functions											
Risk Bearing											
Shadow Pricing											
Externalities						+	+				
Intangibles		+				+					
Distributional Effects											
Sensitivity Analysis	+	+		++		+	+				+
Retrospective Evaluation									+		

Figure 1. Fourteen techniques of cost-benefit analysis as they were applied in the sample of eleven reports. Rows represent the elements defined in Table 1. Entries in each row indicate in which reports, if any, the technique was found and how appropriately it was applied (see text).

#### 3.1. Use of Techniques

##### 3.1.1. Objectives

Most of the reports identified the specific objective of the projects they analyzed.

##### 3.1.2. Alternatives

All the reports identified alternatives. The Trident report specified all the alternatives in full technological detail. The EPICS analysis was especially thorough in specifying assumptions associated with each alternative.

##### 3.1.3. Accounting Stance

No report specifically identified an accounting stance. One may infer that in each case the perspective was intended to be that of decision makers within the service for which the analysis was done.

#### **3.1.4. Decision Criteria**

Most of the reports specified decision criteria, or at least the reader could easily infer the criterion. One, OCIPS, did not and was therefore more a proposal than an analysis of alternatives.

#### **3.1.5. Discounting**

Discounting proved to be the most variable element; applications ranged from no use of discounting at all (OCIPS and MA-3) to one exemplary application. Among the instances of flawed technique, Trident used undiscounted estimates. In the Trident case, the alternatives had similar patterns of expenditure over time, and application of a ten-percent annual discount would have had no effect on the report's conclusions. Similarly, MAINT combined undiscounted estimates, but expenditure patterns were dissimilar. EEMT also used discounting somewhat improperly; annual inflation rates were applied rather than cost-of-borrowing, a social-discount rate or the standard 10 percent. The 6883 report combined costs incurred in the past with future costs for parts of the analysis and in doing so relied on inflation rates for compounding. PREST amortized capital investment costs over a five-year period at zero interest.

On the positive side were analyses that discounted future costs properly, such as MCCBE and EPICS. The PCRS report was especially sophisticated in its approach. It used future values and compounded monthly because benefits accrued that often. An effective monthly rate was properly calculated from the standard 10 percent annual rate, and all discounting and compounding procedures were thoroughly explained in an appendix to the report.

#### **3.1.6. Commensurability**

Most of the analyses were cost-effectiveness studies. One, REPORT, explicitly addressed commensurability. It introduced the assumption that a proxy for the value of additional time served in the Navy (the "benefit") would be the pay and allowances given for such service, thereby monetizing the benefits.

#### **3.1.7. Production Function**

No analysis attempted to fit data to a production function.

#### **3.1.8. Risk Bearing**

The issue of risk management was not incorporated into in any of the analyses, although its relevance was acknowledged in the EPICS report.

#### **3.1.9. Shadow Prices**

No analysis used shadow pricing.

#### **3.1.10. Externalities**

Most of the reports did not consider effects external to the organizational units directly involved. One, PCRS, did suggest the possibility that the productivity and morale of workers in nearby units (organizationally) might be influenced negatively, but no data were gathered to confirm or deny this suggestion. The 6883 analysis reported on the performance of students in

the field following training, and PREST reported performance in follow-on training.

#### **3.1.11. Intangibles**

Most of the analyses did not address intangible effects, but some did. The PCRS report treated extensively questions of employee motivation, potential conflict, and other organizational issues. The 6883 analysis measured attitudes of the trainees.

#### **3.1.12. Distributional Effects**

Not explicitly considered by any report.

#### **3.1.13. Sensitivity Analysis**

The economic analyses included in the sample frequently used some form of sensitivity analysis. PCRS and Trident varied certain parameters. PREST analyzed the implications of future declines in the cost of acquiring computer hardware. REPORT varied assumptions about class size and training duration and, in its basic approach, used *a fortiori* assumptions to avoid overestimating benefits. The MCCBE report included several systematic sensitivity analyses and provided cogent interpretations of these analyses for the decision makers.

#### **3.1.14. Retrospective Evaluation**

The studies in the sample were most often done to aid decisions about implementing a program on a wide-scale. EEMT did develop a "revised" cost model after the device had been engineered. The decision to proceed into engineering development of the device had been based on the original cost model and the data it contained, so the reported costs could have been retrospectively compared to the original ones. The report, however, did not include such a comparison.

### **4. CONCLUSIONS**

Two kinds of conclusions emerge from this review. First, Figure 1 shows an uneven pattern of application of theoretical cost-benefit analysis principles and precepts in the sample of economic analyses. There are specific opportunities to improve the practice of economic analysis in manpower, personnel, and training by more broadly and more consistently drawing on this theoretical base. Second, there are general observations to be made from having reviewed both the theoretical literature in cost-benefit analysis and the practical applications within a limited domain. Along with these observations there are general conclusions to be reached about the future direction of economic analysis of manpower, personnel and training projects and policies. These specific and general conclusions will be taken up in turn.

#### **4.1. Specific Conclusions**

The development and use of *production functions* was the element of cost-benefit analysis judged to have the greatest potential for advancing the practice of economic analyses of manpower, personnel and training programs. Developing a production function necessarily involves making costs and benefits *commensurable*, at least implicitly. Next were assessing *distributional effects*, including *intangibles*, using *shadow prices* and measuring *externalities*. Explicitly stating the *accounting stance* would help in measuring externalities. For varying reasons the following were judged to have some potential for enhancing practice but less than the foregoing elements: *sensitivity analysis and discounting; risk bearing; retrospective*

evaluations. The least potential was found to be associated with the decision-modeling elements: *objective; alternatives; decision criteria*. *Discounting* was the element that was most often incorrectly applied in the sample.

#### 4.1.1. *Production Functions and Commensurability*

Most of the analyses in the sample were cost-effectiveness studies; that is, the goal was to find the least costly way to produce a fixed output. The decision contexts generally implied this approach. Another reason they focussed on costs was that benefits were often difficult to quantify and were especially difficult to value in dollar terms. That is, costs and benefits were not readily commensurable. One could attack the problem directly, but for reasons already discussed, valuing defense products is especially difficult. Another approach, which was suggested by Sassone, is to relate inputs and outputs by an empirically determined production function, which has the effect of equating inputs and outputs.

Once developed, production functions would be useful in resource management. Optimal resource mixes could be estimated quantitatively, for example. With a production function it becomes possible, as noted by Sassone, to value benefits in terms of the costs of the resources needed to purchase them. It also becomes possible to value inputs in the units that measure their benefits, which is the essence of shadow pricing.

#### 4.1.2. *Shadow Pricing*

The price paid for inputs to an organizational unit's productive process often does not reflect the value of the inputs' marginal product or even its value in alternative use within the military. The price of one major class of input, military labor, is fixed by law and is usually accounted for centrally rather than by the budget of the unit that uses it. In an economic analysis the cost of military personnel is usually taken from published data on pay and benefits. However, some ratings or specialties are always in excess supply and others short. A project that requires more scarce personnel in some sense costs more than one that helps balance, say, sea and shore rotations. One way to account for such distortions is to use shadow prices.

#### 4.1.3. *Intangibles*

Both DOD guidance and the economics literature advocate the inclusion of costs and benefits that are intangible, i.e., difficult or impossible to quantify, especially in dollar terms. Figure 1 shows that intangibles are infrequently reported. It is likely that such things as morale, attitudes, and job satisfaction are differentially affected by the alternatives considered in many analyses. Intangible effects should therefore be more systematically included in economic analyses.

#### 4.1.4. *Distributional Effects*

One can argue that, since defense of the society is a product consumed equally by all, there are no distributional effects to consider. However, if one looks within the DOD, within the particular service, and within the organizational elements directly involved, there will generally be individuals who are gainers and those who are losers for any change that is implemented. This becomes especially evident if intangibles are included. Reducing training flight hours for pilots, for example, is likely to reduce their job satisfaction and possibly their future earning potential, although not their present salaries. Frequently the acceptability of a change to the people involved influences its success. Therefore, economic analyses should include distributional considerations, if not in dollar terms at least in an organizational impact analysis.

#### **4.1.5. Accounting Stance and Externalities.**

While the sampled reports were not explicit in identifying an accounting stance, they were nevertheless consistent in viewing costs and benefits from the perspective of the organizational element within the military service for whom the report was prepared. The only recommendation is, therefore, the weak one to be more explicit.

Explicitly identifying the accounting stance might help focus attention on externalities. Budgeting and accounting procedures lead one naturally to adopt an accounting stance that is limited to the organizational element within which decisions will be made about the project one is analyzing. The project's effects, however, tend to spill over into other organizational elements. The example of training economies in one school burdening follow-on schools or operational forces was cited earlier. One theoretical possibility is to broaden the accounting stance, but this becomes unwieldy, and the data may lose their relevance to the decision maker, so it is not done. The alternative is to treat these effects as externalities. If they can be priced, appropriate adjustments can be made to costs and benefits. If not, they can at least be explicitly acknowledged and considered. The conclusion, therefore, is that economic analysis could be improved by more regularly including externalities, a practice that would be helped by explicitly stating the accounting stance.

#### **4.1.6. Sensitivity Analysis and Discounting**

These two elements, like those subsumed under the decision-making heading above, are associated with financial analysis. They were generally used, but not always, and sometimes errors were made. The conclusion therefore is that practice could be improved by routinely conducting sensitivity analyses and by consistently recognizing the time value of money, i.e., by discounting future cash flows. Furthermore, the interest rate one uses in discounting is an obvious candidate for sensitivity analysis.

#### **4.1.7. Risk-bearing**

Manpower, personnel and training programs can have risk-management consequences. A decision to use a simulator in place of some aircraft flights reduces the effects of variations in the price of fuel while possibly constraining options for flight operations, if fewer aircraft are purchased. The reports in the sample did not address such issues of risk-bearing, nor was it obvious that they could have. The conclusion is tentatively that risk management could beneficially be addressed in manpower, personnel and training analyses, although evidence supporting this conclusion is lacking.

#### **4.1.8. Retrospective Analyses**

Like the previous conclusion, the indication is that more such evaluations would be desirable, but the sample of reports does not provide much evidence on this point.

#### **4.1.9. Decision-making Framework**

Inspection of Figure 1 shows that three elements, Objective, Alternatives and Decision Criteria, were generally incorporated into the sample of economic analyses.

## 4.2. General Conclusions

### 4.2.1. *Financial Management and Welfare Economics*

Current practice of economic analysis for defense manpower, personnel and training programs draws heavily on one of the theoretical bases of cost-benefit analysis, financial management. The elements most closely associated with financial management—the decision-making techniques, discounting, sensitivity analysis—were nearly always found in the reports sampled. This conclusion is not surprising when one considers that the documents published within DOD to guide economic analysis concentrate on these elements. A related observation, again consistent with the emphasis in these DOD sources, is that if one distinguishes cost-effectiveness analysis from cost-benefit analysis, it is the former and not the latter that one finds in the sample. Generally, the analyses assume constant benefits, and the techniques most frequently used are appropriate to that stance.

The analyses rested less on the elements associated with welfare economics, which is the other theoretical base of cost-benefit analysis. Externalities, shadow pricing, risk management, intangibles, and distributional effects were infrequently included in the sampled analyses. Given that one accepts the earlier conclusions that these elements are individually applicable to military manpower, personnel and training progress, the general conclusion is that welfare economics has much to offer. Those who require and use cost-benefit analyses, as well as those who do them, ought to consider using these techniques. Beyond specific applications based on welfare economics, how might the opportunity be taken? One possibility would be to create a comprehensive analytic model for defense economic analyses that parallels the model for developing economies that was published by Squire and van der Tak [9]. Theirs has been used by the World Bank and other agencies for project appraisal.

### 4.2.2. *Tradeoff Analyses*

Economic analyses that compare possible alternatives achieve their management purposes and are fine as far as they go. Likewise, the meta-analyses that have been published are extremely helpful for policy makers because they synthesize general conclusions from many specific sources. What neither approach typically provides is the parametric information necessary (1) to generate production functions and (2) to support tradeoff analyses for engineering design and for policy development. The questions one would like to answer are what mix of resources yields the highest output, has the lowest cost, or in general, optimizes a particular objective function? One key to doing this, as suggested earlier, is to develop production functions that mathematically relate input variables to outputs.

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